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The relation between 21st-century skills and digital skills: A systematic literature review

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ABSTRACT

Innovation starts with people, making the human capital within the workforce decisive. In a fast-changing knowledge economy, 21st-century digital skills drive organizations' competitiveness and innovation capacity. Although such skills are seen as crucial, the digital aspect integrated with 21st-century skills is not yet sufficiently defined. The main objectives of this study were to (1) examine the relation between 21st-century skills and digital skills; and (2) provide a framework of 21st-century digital skills with conceptual dimensions and key operational components aimed at the knowledge worker. A systematic literature review was conducted to synthesize the relevant academic literature concerned with 21st-century digital skills. In total, 1592 different articles were screened from which 75 articles met the predefined inclusion criteria. The results show that 21st-century skills are broader than digital skills – the list of mentioned skills is far more extensive. In addition, in contrast to digital skills, 21st-century skills are not necessarily underpinned by ICT. Furthermore, we identified seven core skills: technical, information management, communication, collaboration, creativity, critical thinking and problem solving. Five contextual skills were also identified: ethical awareness, cultural awareness, flexibility, self-direction and lifelong learning.

1. Introduction

In the knowledge society, organizations operate in a global economy characterized by intense competition together with economic interdependence and collaboration. By globalizing the production of goods and services, thousands of jobs, particularly in manufacturing, have been eliminated by automation or relocation to industrialized countries (Anderson, 2008; Levy & Murnane, 2012). Furthermore, flexible production and service delivery systems cause profound changes in the workplace such as flatter management structures, decentralized decision making, information sharing and task teams, cross-organizational networking and flexible work arrangements (Partnership for 21st century skills, 2008). Information and communication technologies (ICTs) are at the core of this fast-changing economy. However, although ICTs are a foundation for innovation, in themselves they do not create a knowledge-based economy. Innovation starts with people, making the human capital within the workforce decisive (Anderson, 2008; Kefela, 2010; Lanvin & Kralik, 2009; Lanvin & Passman, 2008). The current workplace requires highly skilled workers faced with increasingly complex and interactive tasks. Such workers are expected to efficiently select knowledge from the amount of available information and effectively apply such knowledge, both in their professional and personal lives. Employees not only need excellent technical preparation; they also need sufficient skills to adapt to the changing requirements of the job (Ahmad, Karim, Din, & Albakri, 2013; Carnevale & Smith, 2013). Knowledge has become vital in the 21st-century and people need to acquire such skills to enter the workforce – called 21st-century skills. In general, 21st-century skills include collaboration, communication, digital literacy, citizenship, problem solving, critical thinking, creativity and productivity (Voogt & Roblin, 2012). These skills are labelled 21st-century skills to indicate that they are more related to the current economic and social developments than with those of the past century characterized as an industrial mode of production.

The development of the global knowledge society and the rapid integration of ICT make it imperative to acquire digital skills

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necessary for employment and participation in society. In addition, together with changes in the job markets, 21st-century skills such as searching and evaluating information, solving problems, exchanging information or developing ideas in a digital context are perceived as essential. These developments ask for increased attention to the identification and acquisition of the competences individuals need to actively and effectively participate in the knowledge society (Ananiadou & Claro, 2009). Although 21st-century skills and digital skills are both seen as crucial, the combination is not yet sufficiently defined. In this respect, the concept of '21st-century digital skills' is introduced. Such skills are critical for both people and organizations for keeping up with developments and innovating products and processes. Lewin and McNicol (2015) state that the growing impact of globalisation and the knowledge society have led many to argue that 21st-century skills are essential to be successful in the workplace and that ICT is central to their development. Importantly, these skills go beyond the mere technical annotation. How someone thinks, solves problems, and learns, has a greater impact on a person's ability to function in a technologically rich society than just being knowledgeable about specific software (e.g. Ahmad et al., 2013; Claro et al., 2012; Eshet-Alkalai, 2004). In line with Claro et al. (2012), we consider 21st-century digital skills as: (1) the mastery of ICT applications to solve cognitive tasks at work; (2) skills that are not technology-driven, as they do not refer to the use of any particular software program; (3) skills that support higher-order thinking processes; and (4) skills related to cognitive processes favoring employees' continuous learning.

The current study has three objectives. The first objective is to identify the concepts being used to describe the skills needed in a digital environment, go beyond mere technical use, and focus on 21st-century digital skills. The next section inventories the various concepts that are used to define the human attributes associated with ICT use. The following research question is addressed:

- *Which concepts are being used to describe the skills needed in a digital environment, go beyond mere technical use, and focus on 21st-century digital skills?*

The second objective is to define the relation between 21st-century skills and digital skills. In addition, the third objective is to provide a framework of 21st-century digital skills with a conceptual definition and key operational components aimed at knowledge workers. A systematic literature review is conducted to synthesize the relevant academic literature concerned with 21st-century digital skills. The objectives are approached by addressing the following research questions:

- *Which selection is being made to synthesize the relevant literature concerned with 21st-century digital skills?*
- *Which concepts are being used?*
- *What is the particular field of study?*
- *Which research methods are being used?*
- *Which skills are mentioned as being essential for the workforce?*
- *How are the mentioned skills conceptualized?*
- *How are the mentioned skills operationalized?*

2. Theoretical framework

This section identifies various conceptualizations that describe the skills needed in a digital environment. It will be pointed out the extent to which the identified concepts integrate the digital aspect with 21st-century skills. To find the most suitable concepts to guide our systematic literature review, a distinction is made between: (1) technological skills concepts; (2) 21st-century skills concepts; and (3) 21st-century digital skills concepts.

2.1. Technological skills concepts

Various terms are used to define the human attributes associated with ICT use. With the spread of digital technologies, terms such as IT, ICT and computer literacy have become prevalent (Bawden, 2008). The technology plays a dominant role in defining which skills are considered important. In most cases, these concepts consist of a domain part (e.g. computer, ICT, internet, multimedia) in combination with a specific knowledge perspective (e.g. competence, literacy, skills) (Hatlevik, Ottestad, & Throndsen, 2015). These concepts primarily indicate a basic set of skills in using computers or Internet technology; for example, turning off the computer, opening a folder and saving a file. They do not go far enough to explain the skills an individual must possess to exploit the full potential of ICT. However, those technical skills are a driving force behind the need for 21st-century skills and required for the acquisition of 21st-century digital skills.

2.2. 21st-century skills concepts

'Digital competence' has become a key concept in the discussion of what kind of skills and understanding citizens must have in the knowledge society. Although the term encompass 'digital', the digital aspect is often seen as a discrete skill – implying that the 21st-century skills are not necessarily underpinned by ICT. Digital competence covers information management, collaboration, communication and sharing, creation of content and knowledge, ethics and responsibility, evaluation and problem solving and technical operations (Ferrari, 2012). Similar aspects are put forward in '21st-century skills' definitions. The promise of 21st-century learning is that digital technologies will transform traditional learning and mobilize those skills that are necessary in an emerging digital environment. A detailed conceptual framework is taken from the Partnership for 21st Century (P21). The P21 (2008) lists three types of skills: learning skills (creativity and innovation, critical thinking and problem solving, communication and collaboration), literacy skills (information, media and ICT literacy) and life skills (flexibility and adaptability, initiative and self-direction, social and cross-cultural skills, productivity and accountability, leadership and responsibility). Other groups and organizations have proposed similar frameworks. The Assessing and Teaching of 21st Century Skills (ATC21S), for example, used an expert group to define key 21st-century skills (Binkley et al., 2012). They categorized 21st-century skills as follows: Ways of Thinking (creativity and innovation; critical thinking, problem solving, and decision making; learning to learn and metacognition), Ways of Working (communication; collaboration and teamwork), Tools for Working (information literacy; information technology and communication literacy), and Living in the World (life and career; personal and social responsibility). The main focus is on the teaching and learning practices to ensure students' mastery of 21st-century skills in the classroom as preparation for working life (Leahy & Dolan, 2010).

2.3. 21st-century digital skills concepts

Only a few approaches provide an integration of 'digital' and 21st-century skills. First, 'digital literacy', introduced by Gilster (1998), is considered as the ability to understand and to use information from a variety of digital sources. Digital literacy is

distinguished from the more limited technical skills view of digital literacy by explicitly stating that "digital literacy is about mastering ideas, not keystrokes" (p. 1–2). Thus, digital literacy must be more than the ability to use digital sources effectively. Eshet-Alkalai (2004) published a conceptual model of survival skills for digital literacy, besides involving the ability to use software or operate a digital device, also stressing cognitive and social-emotional skills in order to perform tasks and solve problems in digital environments. Ng (2012) distinguished three intersecting dimensions that are the technical, cognitive and social-emotional dimensions of digital literacy. Overall, digital literacy is presented as a mind-set that enables users to perform intuitively in digital environments, and to both easily and effectively access the wide range of knowledge embedded in such environments (Martin, 2008). Moreover, Van Deursen and Van Dijk (2010) proposed a range of 'digital skills' conceptualizations, accounting for technical or media aspects (medium-related skills) and substantial or content aspects (content-related skills), more specifically operational, formal, information, communication, content creation and strategic skills (Van Deursen, Helsper, & Eynon, 2016). That proposed definition avoids a technologically deterministic viewpoint by accounting for technical aspects and the aspects related to the content provided by the Internet. Finally, the concept of 'e-skills' focusses on the question of what an organization should do with ICT. Mitrovic (2010) explains e-skills as "the ability to develop and use ICT to adequately participate in an environment increasingly dominated by access to electronically-enabled information, and a well-developed ability to synthesize this information into effective and relevant knowledge" (p. 2).

To conclude, despite the lack consistency in the terms used, many concepts have been put forward in response to the skills needed in the new social and technological environments. In our systematic literature review the focus is on skills needed in a digital environment, go beyond mere technical use, and focus on 21st-century digital skills. Therefore, we take into account: digital competence, digital literacy, digital skills, e-skills, 21st-century (learning or thinking) skills and 21st-century competence.

3. Method

3.1. Systematic literature review

A systematic literature review is a review of "a clearly formulated question that uses systematic and explicit methods to identify, select, and critically appraise relevant research and to collect and analyze data from the studies that are included in the review" (Moher, Liberati, Tetzlaff, & Altman, 2009, p. 264). This method was chosen, because it helps to synthesize academic literature in an accurate and reliable manner. In our case, we look systematically at articles that categorize 21st-century digital skills. The systematic literature review was conducted in accordance with the Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA) approach (Moher et al., 2015). The PRISMA approach entails an evidence-based checklist of 27 items and a four-phase flow diagram. The checklist items were included if there was evidence that not reporting the item was associated with increased risk of bias, or where it was clear that information was necessary to appraise the reliability of a review (Liberati et al., 2012). PRISMA is not intended to be a quality assessment tool, but the aim is to ensure clarity and transparency when reporting systematic literature reviews. The PRISMA checklist of 27 items and four-phase flow diagram were used to report our results.

3.2. Search terms

The search action was conducted using the Scopus, Web of Science and PsycINFO databases which are three well-established databases in the social sciences. The search action included 21st-century digital skills related terms in agreement with terms for the operationalization. For each construct, we used several keywords to make sure a broad coverage of studies. Each database has its own indexing terms, therefore; individual proximity operators were used. As a result, the following Boolean search action was conducted:

("21st-century competenc*" OR "21st-century (NEAR/2) skills" OR "twenty-first century (NEAR/2) skills" OR 21st-century learning skills OR twenty-first century learning skills OR 21st-century thinking skills OR twenty-first century thinking skills"" OR "digital competenc*" OR "digital (NEAR/2) skills" OR "digital literacy" OR "e-skills") AND (defin* OR frame* OR measur* OR model OR review).

3.3. Selection criteria

A number of criteria were specified to select the most relevant studies. In all three databases, the limitations of document type, 'peer-reviewed articles', language, 'English' and time period, '2000–2016', was added. To be included, articles had to fulfil the four criteria defined below.

1. Focus on 21st-century skills dimensions or a related term. The technical aspect may be discussed in addition to the 21st-century skills dimensions. A precondition because a limited amount of research focuses on 21st-century digital skills.
2. Include conceptualizations or an actual measurement of 21st-century (digital) skills or a related term. This criterion was selected to create a 21st-century digital skills framework based on academic literature.
3. Mention the term in context of workforce preparation. A precondition, because the main aim of this study is to propose a framework relevant to the current workforce.
4. Be published in a peer-reviewed journal. This latter criterion was used since journals are considered as the most reliable source of scientific information.

3.4. Study selection

The study selection was made in three steps. First, the titles of all retrieved articles were screened for eligibility for the above-mentioned inclusion criteria. Second, the abstracts of all initially relevant articles were screened for eligibility by applying uniform criteria. Finally, the full-text of all remaining publications was checked. All articles deemed relevant were coded in terms of: name of authors, date published, journal, the main aims, method, mentioned skills, definition and operationalization of skills, results and conclusion. Coding of the articles was done to make sure all articles that fulfilled the four criteria were selected. Based on this document, we extracted information about study field, study type, main concept, list of skills, and if skills were conceptualized or operationalized of all selected articles. Data extraction is part of the content-analysis process to make an overview of the characteristics of all articles that were included in our research. The final part of the content-analysis process consisted of looking at how the skills were conceptualized and operationalized to not only list the mentioned skills, but to also provide the skills with a conceptual definition and operational components.

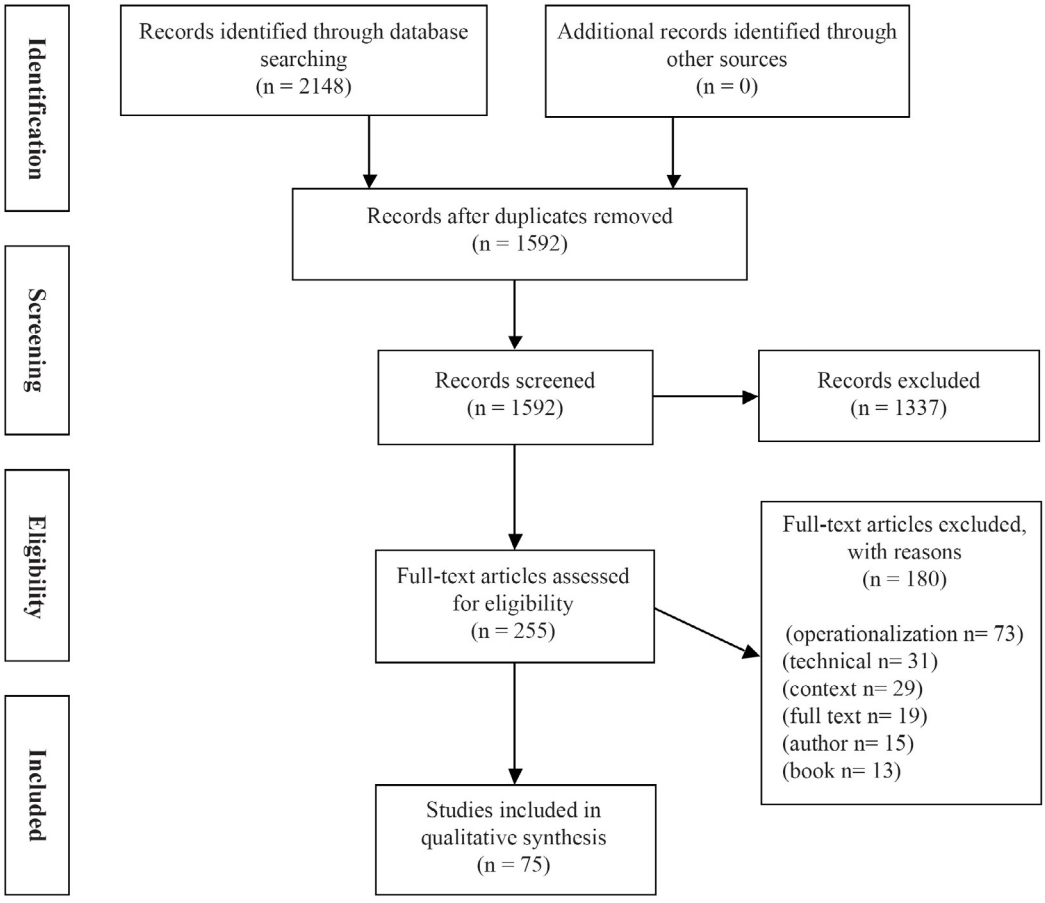

Fig. 1. PRISMA flowchart.

3.5. PRISMA flowchart

Given the restrictions of document type, language and time period, 2148 articles were identified from the databases. Out of the 2148, 556 were duplicates which means 1592 different articles were screened. After title and abstract screening, 255 were read in full-text from which 75 articles met all four inclusion criteria. Fig. 1 presents the flowchart for the selection of the included studies. Additional records were not identified through other sources, because the references of the included articles did not contribute to the received information. There were six reasons for excluding a full-text screening: (1) not containing a 21st-century (digital) skills operationalization; (2) only focused on the technical aspect; (3) not mentioned in the context of workforce preparation; (4) not a peer-reviewed journal article; (5) no full-text available online; and (6) duplicated first authors. If there were several suitable articles with a duplicated first author, we selected the most recent available article.

3.6. Selection bias

To assess quality of the study, a sample of the articles was independently coded by a second coder. Publication bias in a systematic literature review occurs mostly during the selection process and a transparent selection process is necessary to minimize such bias (Moher et al., 2015). The Scopus database was chosen to execute the search action, because this is the largest abstract and citation database of peer-reviewed literature. A second coder performed the search action and followed the study selection steps of title, abstract and full-text evaluation according to a predefined instruction. Based on the eligibility criteria, the second coder decided whether or not to closely examine an article. If the article was read in full-text and not selected, the reason for not including the article was provided. Cohen's kappa coefficient is a statistic which measures inter-rater agreement. In the first round of coding with twenty-five percent of the articles, the inter-rater reliability was not good among the coders and, therefore, a second round of coding with fifteen percent of the articles was performed. Between the two code rounds, the criteria were specified to clarify the ambiguity. After the specification of the criteria, the inter-rater reliability in the second round for 120 selected articles was 0,701 which shows good agreement between the two coders.

To ensure the validity of the coding and to avoid researcher bias in coding the study characteristics, we also conducted a coding session for the main findings of the systematic literature review. A second coder randomly selected twenty percent of the 75 included articles and wrote down the mentioned skills. After that, the mentioned skills had to be coded based on our framework of skills and a separate code for the remaining skills that were not in the framework. A Cohen's kappa of 0,820 was achieved, denoting good agreement between the two coders. After

the coding sessions, all disagreements were resolved through discussion to reach consensus.

4. Results

4.1. Content-analysis

Appendix A provides an overview of the skills mentioned in the included articles and the main concept being used. Overall, the articles were diverse in scope, addressed various 21st-century skills dimensions, utilized a range of theoretical models and adopted a variety of methodological approaches.

4.1.1. Study type and field

Table 1 provides an overview of the various study types and fields. To clarify, a review must cover all of the scientific literature in a field that is defined by the author, while a theoretical analysis only includes references to those works that are necessary for the analysis. The results indicate that surveys were the most commonly employed type of study (n = 22) followed by theoretical studies (n = 14) and performance tests (n = 12). Although there were twelve performance assessments, five focused on one particular skill problem solving and referred to the MicroDYN approach proposed by Greiff, Wüstenberg, and Funke (2012). A limited number of studies used large-scale performance tests in which participants were asked to complete assignments. Most studies did not determine participants' exact skill levels, but relied on the self-assessment of participants. In total, 35 studies (survey, mixed method, case-study Delphi-study, and experiment) relied on self-assessment in comparison with 12 performance test studies.

For the categorization of studies fields, Scopus journal classification of subject categories was used. In case of multiple categories, the most convenient field was chosen. Based on the categorization, it became clear that Education is the most prevalent study field (n = 27). In addition, there are many studies referring to the educational field. For instance, Computer Science and Education (n = 17) and Engineering and Education (n = 4).

4.1.2. Overview concepts

Table 2 presents an overview of the concepts being used in the articles. Remarkably, e-skills is never mentioned as key concept. Clearly, most articles refer to 21st-century skills (n = 35). Those articles focus on teaching and learning practices to ensure students mastery of 21st-century skills in the classroom as preparation for working life. As a consequence, students were the main participant group and not the working population.

4.1.3. 21st-century skills dimensions

Table 3 shows the numbers of articles that addressed the various 21st-century skills dimensions. In total, 75 articles were included from which ten percent, seven articles, have to mention a

Table 2
Concepts used included articles (n = 75).

Term	n
21st-century (or twenty-first) skills	35
Digital literacy	8
Digital skills	5
21st-century (or twenty-first) learning skills	5
Digital competence	5
Information literacy	5
21st-century (or twenty-first) competence	3
21st-century (or twenty-first) thinking skills	3
Transversal (or transferable) skills	2
21st-century ICT literacy	1
21st-century ICT skills	1
New media literacy	1
Multiliteracy	1

Table 1
Study characteristics included articles (n = 75).

		Operational	Operational	Conceptual	Conceptual	n
		Single skill	Multiple skills	Single skill	Multiple skills	
Study type	Case-study	1	2			3
	Comparative-analysis				3	3
	Content-analysis				1	1
	Delphi-study		1		1	2
	Experiment	1				1
	Mixed method		7			7
	Performance test	7	5			12
	Review			4	6	10
	Survey	6	14		2	22
	Theoretical			6	8	14
	Total	15	29	10	21	75
Study Field	Agriculture Biological Sciences, Education		1			1
	Arts and Humanities		1	1		2
	Business and International Management				1	1
	Business, Management and Accounting	1				1
	Computer Networks, Communications		1			1
	Computer Science, Education	5	8		4	17
	Communication		3			3
	Developmental and Educational Psychology		1	1	2	4
	Education	7	9	3	8	27
	Engineering, Education	1	1	1	1	4
	Human-Computer Interaction		2		1	3
	Language and Linguistics				1	1
	Library and Information Sciences	1	1	2	1	5
	Management of Technology and Innovation, Education				1	1
	Psychology		1	1	1	3
	Strategy, Management, Education				1	1
	Total	15	29	10	21	75

Table 3
Skills mentioned included articles (n = 75).

	Operational	Conceptual	n
Information management	16	15	31
Critical thinking	18	12	30
Creativity	12	17	29
Problem solving	11	13	24
Collaboration	11	13	24
Communication	11	11	22
Technical	12	6	18
Self-direction	6	10	16
Lifelong learning	4	6	10
Ethical awareness	5	4	9
Cultural awareness	2	7	9
Flexibility	2	6	8

skill to be included in the framework. The most frequently reported skills were information management (n = 31), critical thinking (n = 30), creativity (n = 29), problem solving (n = 24), collaboration (n = 24) and communication (n = 22). Furthermore, a distinction is made between articles that only conceptualize skills and articles that attempt to measure such skills. Critical thinking (n = 18), information management (n = 16), technical (n = 12), and problem solving (n = 11) were the most thoroughly examined skills. Overall, 21st-century skills or digital competence refer to an extensive list of skills on conceptual level while digital skills or digital literacy often refer to a limited number of skills on operational level.

4.1.4. Relation between 21st-century skills and digital skills

21st-century skills and digital competence are both concepts that emphasize a broad spectrum of skills. Beyond skills, knowledge and attitude are viewed as essential to thrive in the knowledge society. The list of mentioned skills is extensive, but both concepts do not integrate the digital aspect. The digital aspect is often seen as a discrete skill – implying that 21st-century skills are not necessarily underpinned by ICT. Furthermore, many 21st-century skills categorizations and conceptualizations are given, but only a few frameworks are available to provide operational components. In addition, if an operationalization is provided, the focus is often on one particular skill. The main difference with digital skills or digital literacy is that these concepts do provide the 21st-century digital skills integration. Although the skills being mentioned are moving towards the knowledge-related skills, they do not cover the broad spectrum of 21st-century skills. However, the skills being mentioned are more thoroughly measured in comparison with 21st-century skills or digital competence. Overall, the focus is on knowledge- or content-related skills. In addition, research tend to focus on citizens or students instead of skills required for the workforce.

4.2. Conceptual 21st-century digital skills framework

21st-century skills and digital skills are both seen as crucial, but the combination is not yet sufficiently defined. To conceptualize the 21st-century digital skills dimensions, we took into account those descriptions available in the included articles. For each included article, we list the skills conceptualizations and operational components. Based on the results, a distinction is made between the core skills (Table 4) and the contextual skills (Table 5). The core skills are fundamental for performing tasks that are necessary in a broad range of occupations. Contextual skills are those skills that are required to take advantage of the core skills and, therefore, must be connected to such core skills. For each skill, a conceptual definition with key operational components are provided. It has to be noticed that the digital aspect for the contextual skills – cultural awareness, flexibility and self-direction – was added by the researcher. There was no article available that made a connection towards the digital aspect.

5. Discussion

5.1. Main findings

The first objective of this study was to identify the concepts being used to describe the skills needed in a digital environment, go beyond mere technical use, and focus on 21st-century digital skills. The theoretical framework identified various concepts: 21st-century (learning or thinking) skills, digital competence, digital literacy, digital skills and e-skills. Clearly, concepts are moving into the direction where they take into account knowledge- or content-related skills. Although the importance of 21st-century skills and digital skills have been well established, the relation between both concepts was not yet sufficiently defined. The second objective was to define the relation between two main concepts: 21st-century skills and digital skills. In addition, the third objective was to provide a framework of 21st-century digital skills with a conceptual definition and key operational components aimed at knowledge workers. These objectives were approached by systematically synthesizing the relevant academic literature concerned with 21st-century digital skills. Multiple research question were addressed about the concept and method being used, the study field, the mentioned skills and how they were conceptualized or operationalized. A systematic literature review methodology was followed to address transparency and replicability (Jesson, Matheson, & Lacey, 2011). The systematic literature review identified 75 articles that met the predefined inclusion criteria. Based on the characteristics of the 75 included articles, the results show that 21st-century skills are broader than digital skills – beyond skills, knowledge and attitude are viewed as essential to thrive in the knowledge society. Besides, the 21st-century skills are not necessarily underpinned by ICT, while digital skills or literacy do provide such integration. Furthermore, many 21st-century skills categorizations are given, but only a few frameworks are available to provide operational components. The digital skills being mentioned are more thoroughly measured in comparison with 21st-century skills. Both concepts tend to focus on citizens' or students' levels of skills and not on skills for the workforce. However, they did help to establish a conceptual 21st-century digital skills framework with key operational components aimed at knowledge workers as presented in Tables 4 and 5 To create this framework, this study systematically identified key 21st-century skills or digital skills dimensions by evaluating articles that aim to define or measure them. It has resulted in a framework of seven core skills: technical, information management, communication, collaboration, creativity, critical thinking and problem solving, and five contextual skills: ethical awareness, cultural awareness, flexibility, self-direction and lifelong learning. In a global knowledge economy, those skills to a great extent determine organizations' competitiveness and the capacity to drive innovation. Given the rapid rate of change and the influence of technology, employees need to develop 21st-century digital skills to cope and thrive in this changing society. Although 21st-century digital skills were viewed as essential, they were not yet ultimately covered in published research. Therefore, this study has taken a first step to close this research gap. This study has extended our understanding and categorization of 21st-century digital skills, but it also contains points for discussion.

Table 4
Framework with core 21st-century digital skills.

21st-century digital skills dimensions	Conceptual definition with operational components
Technical	The skills to use (mobile) devices and applications to accomplish practical tasks and recognize specific online environments to navigate and maintain orientation. Key components (e.g. Ng, 2012; Van Deursen et al., 2016): - ICT knowledge: understand the characteristics of (mobile) devices or applications. - ICT usage: operate basic (mobile) application operations and access resources for everyday use. - Navigation: avoid losing orientation when navigating online.
Information management	The skills to use ICT to efficiently search, select, organize information to make informed decisions about the most suitable sources of information for a given task. Key components (e.g. Ahmad et al., 2016; Snow & Katz, 2009): - Define: use ICT to formulate a research statement to facilitate the search for information. - Access: use ICT to find and retrieve information from a variety of online sources. - Evaluate: use ICT to judge the usefulness and sufficiency of information for a specific purpose. - Manage: use ICT to organize information so as to be able to find it later.
Communication	The skills to use ICT to transmit information to others, ensuring that the meaning is expressed effectively. Key components (e.g. Claro et al., 2012; Siddiq, Scherer, & Tondeur, 2016): - Transmitting information: use ICT to communicate information and ideas effectively to multiple audiences using a variety of media and online formats.
Collaboration	The skills to use ICT to develop a social network and work in a team to exchange information, negotiate agreements, and make decisions with mutual respect for each other towards achieving a common goal. Key components (e.g. Choy, Deng, Chai, Koh, & Tsai, 2016; Helsper & Eynon, 2013): Interactive communication: generate meaning through exchanges using a range of contemporary ICT tools. - Interactive communication: generate meaning through exchanges using a range of contemporary ICT tools. - Participation in discussions: use ICT to share ideas (e.g. in online platforms).
Creativity	The skills to use ICT to generate new or previously unknown ideas, or treat familiar ideas in a new way and transform such ideas into a product, service or process that is recognized as novel within a particular domain. Key components (e.g. Hinrichsen & Coombs, 2013; Mengual-Andrés, Roig-Vila, & Mira, 2016): - Content creation: use ICT to generate ideas or develop new ways of doing things.
Critical thinking	The skills to use ICT to make informed judgements and choices about obtained information and communication using reflective reasoning and sufficient evidence to support the claims. Key components (e.g. Greene, Yu, & Copeland, 2014; Lee et al., 2016): - Clarification: use ICT to ask and answer questions of clarification related to the problem. - Assessment: use ICT to judge the suitability of a source for a given problem. - Justification: use ICT to invoke arguments for claims based upon their consistency with other knowledge claims (e.g. personal, memory, testimony, coherence, rationality, replication). - Linking ideas: use ICT to link facts, ideas and notions. - Novelty: use ICT to suggest new ideas for discussion.
Problem solving	The skills to use ICT to cognitively process and understand a problem situation in combination with the active use of knowledge to find a solution to a problem. Key components (e.g. Greiff, Wüstenberg, Holt, Goldhammer, & Funke, 2013; Scherer & Gustafsson, 2015): - Knowledge acquisition: use ICT to acquire implicit and/or explicit knowledge about the problem. - Knowledge application: use ICT to apply implicit and/or explicit knowledge about the problem to find a solution.

Table 5
Framework with contextual 21st-century digital skills.

21st-century digital skills dimensions	Conceptual definition with operational components
Ethical awareness	The skills to behave in a socially responsible way, demonstrating awareness and knowledge of legal and ethical aspects when using ICT. Key components (e.g. Claro et al., 2012; Janssen et al., 2013): - ICT responsible use: decide about the legal, ethical and cultural limits of personally and socially responsible use of ICT, by understanding potential risks that exist on the Internet when using ICT. - ICT social impact: understand, analyze and evaluate the impact of ICT in social, economic and cultural contexts when using ICT.
Cultural awareness	The skills to show cultural understanding and respect other cultures when using ICT. Key components (e.g. Yang, Huiju, Cen, & Huang, 2014; Young, 2015): - Cross-cultural communication: attitudes towards online communication and collaboration experiences with people from different cultures when using ICT.
Flexibility	The skills to adapt one's thinking, attitude or behavior to changing ICT environments. Key components (e.g. Anderman, Sinatra, & Gray, 2012; Osman, Hamid, & Hassan, 2009): - Adapting to frequent and uncertain situations: attitude towards modify one's thinking, attitudes, or behaviors to be better suited to current or future ICT environments.
Self-direction	The skills to set goals for yourself and manage progression toward reaching those goals in order to assess your own progress when using ICT. Key components (e.g. Holt & Brockett, 2012; Quieng, Lim, & Lucas, 2015): - Goal setting: state learning or time goals when using ICT. - Control: willingness of individuals to take control of their own learning when using ICT. - Initiative: proactively take steps toward decisions and/or actions when using ICT. - Monitor progress: assess whether previously-set goals have been met when using ICT.
Lifelong learning	The skills to constantly explore new opportunities when using ICT that can be integrated into an environment to continually improve one's capabilities. Key components (Chai, Deng, Tsai, Koh, & Tsai, 2015; Uzunboylu & Hürsen, 2011): - Knowledge creation efficacy: use ICT to create useful knowledge individually.

5.2. Limitations

The systematic literature review was limited by focusing on the literature from the past sixteen years and specifically focusing only on peer-reviewed articles to ground our understanding of 21st-century digital skills in research evidence. Consequently, this review might have excluded relevant articles published before the year 2000 and relevant books or conference papers. Furthermore, a limited number of articles were available about 21st-century digital skills that are conceptualized or measured within the workforce. Therefore, the criteria was that articles have to mention the skills as preparation for work. This criteria means that the educational context is not necessarily excluded. The articles that discussed the skills only in the classroom, often primary education, were excluded – it has to make the connection to those skills beyond the classroom. It is expected that many of the ideas discussed in the educational context will also be relevant to understanding 21st-century digital skills for work. However, the dynamic changes in the types of jobs demanded by the knowledge society pose serious challenges to educational systems, as they are currently asked to prepare young people for jobs that may not yet exist (Voogt, Erstad, Dede, & Mishra, 2013). In addition, research also state that there is a mismatch between the qualifications of graduates and the skills demanded by jobs (Cobo, 2013; Soule & Warrick, 2015).

Several limitations must be noted concerning the process of creating our framework. First of all, the digital aspect was not ultimately covered in the included studies, because 21st-century skills was the most popular term. In addition, the articles that do integrate the digital aspect, do not cover the broad range of 21st-century skills. As a result, it was difficult to conceptualize the digital aspect for all twelve skills. Especially for the contextual skills, we used the conceptual definitions provided by the literature, but added the digital aspect for ourselves.

Furthermore, the 21st-century digital skills framework is based on the decision rule: seven articles have to mention the skill to be included. This rule has resulted, for example, in the fact that entrepreneurial skills were excluded, because they were just five times mentioned. Entrepreneurial skills could be of relevance for the workforce context, because it emphasizes a person's innovation capacity and ability to perceive new opportunities to market. Moreover, lifelong learning was more than seven times recognized as an important 21st-century digital skill. However, lifelong learning could also be perceived as an approach instead of a skill. “Lifelong learning is a continuous, voluntary, and self-motivated act to expand one's own knowledge” (Kaur & Beri, 2016, p.1365). It is a mind-set meaning that learning – gaining new skills and new knowledge – is a lifetime opportunity and achievement. Therefore, it could be questioned if lifelong learning is a 21st-century digital skill.

5.3. Future research directions

Our inclusion criteria identified 75 articles that provided conceptualizations or measurement of 21st-century digital skills, suggesting that concerns about the lack of empirical evidence in this area are recognized. A few dimensions – technical, information management, critical thinking and problem solving – were studied in more detail. The majority of measurements examined facets such as ICT usage (technical), define, access, manage and evaluate digital information (information management), justification (critical thinking), and the active use of knowledge to find a solution (problem solving). Although 21st-century skills have been widely recognized, the main emphasis in assessment is still on the functional skills such as technical knowledge and usage (Ahonen & Kinnunen, 2015). Ahonen and Kinnunen (2015) revealed that students rated social skills and collaboration as the most important competences needed in the future. Our systematic literature review shows a lack of extensive tests targeting students' soft skills, understood to be behavioral and other non-technical skills (Cobo, 2013). One conceivable explanation for why some skills are measured more frequently than others is that soft skills are regarded as hard to observe, quantify or measure (Cobo, 2013; Silva, 2009). Another explanation is that the list of 21st-century skills is extensive and it is therefore impossible to develop one test that covers all such skills (Aesaert & Van Braak, 2015). Many 21st-century skills categorizations are given to an extended range of terms, but only a few frameworks are available to provide operational components. Although we have provided researchers with some key operational components for each skill, future researchers could further elaborate on those.

Another future research direction is that the majority of measurement tools available target secondary students, pointing to the lack of tests targeting employees, and thus motivating the development of tests for these groups of participants. Besides, a considerable proportion of the measures developed for gauging participants' skills are based on self-reports, in which they are asked to evaluate how well they perform on certain skills-related tasks (Aesaert, Van Nijlen, Vanderlinde, & Van Braak, 2014). Such indirect measures have been recognized as challenging as they only provide rough proxies for actual competences. The increasing attention given to 21st-century skills has also resulted in an increasing interest in whether and how to include the assessment of these skills in large-scale tests. Assessments allow us to determine to what extent employees have obtained the 21st-century digital skills needed to enable them to be productive members of an information-rich and technology-based society (Ahmad et al., 2013). If the argument of the centrality of 21st-century digital skills for employability is accepted, then data should become available about the actual skills level within the workforce. Performance tests are a suitable measurement tool for future research to provide a more realistic view of employees' skills level since a variety of indicators can be automatically achieved. Given that a tradition of measuring the various aspects of 21st-century digital skills has not yet been established, it is useful to carry out more smaller in-depth qualitative studies before launching large-scale quantitative assessments.

6. Concluding remarks

The premise of this study was that to meet the demands of the workforce, it is necessary to propose an expanded conceptual framework that includes 21st-century digital skills. This study goes beyond the basic technical abilities and searched for the digital equivalent of 21st-century skills. The vision of 21st-century digital skills is that those skills are needed to participate in the knowledge-based workforce and to put employees in charge of their own learning. The essence is what employees can do with knowledge to support 21st-century skills and take full advantage of ICT. Defining 21st-century digital skills as precisely as possible is an essential first step to identify, and possibly quantify, current and expected needs.

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Appendix A

Table 1Included studies

Author/Year	21st-century skills dimensions	Main concept
Aharony and Bronstein (2013)	Information literacy	Information literacy
Ahmad et al. (2016)	Defining, accessing, evaluating, managing, integrating, creating, communicating	21st-century ICT literacy
Ahonen and Kinnunen (2015)	Collaboration, problem solving, creativity, communication, critical thinking, information literacy, technical proficiency, citizenship, independent Initiative, work skills, cultural awareness, social responsibility, learning skills and lifelong learning, ecological awareness	Twenty-first century skills
Alozie, Grueber, and Dereski (2012)	Adaptability, complex communication/social skills, non-routine problem solving, self-management/self-development, systems thinking	21st-century skills
Anderman et al. (2012)	Adaptability, complex communication/social skills, non-routine problem solving skills, self-management/self-development, systems thinking	Twenty-first century skills
Barak (2016)	Adapting to frequent changes and uncertain situations, collaborating and communicating in decentralized environments, generating data and managing information, releasing control by encouraging exploration	Twenty-first century competence
Barbot, Besançon, and Lubart (2015)	Creativity	Twenty-first century skills
Boyaci and Atalay (2016)	Creativity and innovation, critical thinking and problem solving, cooperation and communication	21st-century learning skills
Calvani, Fini, Ranieri, and Picci (2012)	ICT Knowledge, including VL, TS, UTC; High-order cognitive skills, involving OCTVD, OSD, IR; Ethical knowledge, which includes SSO, RON and USTI	Digital competence
Care, Scoular, and Griffin (2016)	Collaborative problem solving	21st-century skills
Caviglia and Delfino (2015)	Information problem solving	Digital literacy
Chai et al. (2015)	Self-directed learning, collaborative learning, meaningful learning with technology, critical thinking, creative thinking, authentic problem solving, knowledge creation efficacy	Twenty-first century learning skills
Choi, Lee, Shin, Kim, and Krajcik (2011)	Communication, collaboration, systematic thinking, use of evidence to support claims, information management, self-directed planning, monitoring, evaluation	Twenty-first century thinking skills
Choy et al. (2016)	Self-directed learning, collaborative learning	21st-century skills
Claro et al. (2012)	ICT fluency/skill in sourcing for information, ICT skills in processing information, ICT skills in effective communication, ICT skills in collaboration and virtual interactions, ICT responsible use, ICT social impact	21st-century ICT skills
Cobo (2013)	Collaboration, critical thinking, contextual learning, searching, synthesizing and disseminating information, communication, self-direction, creativity	21st-century skills
De Bie, Wilhelm, and Van der Meij (2015)	Critical thinking	21st-century skills
DiCerbo (2014)	Task persistence	21st-century skills
Donovan, Green, and Mason (2014)	Creativity and innovation, critical thinking and problem solving, communication, collaboration	21st-century skills
Dwyer, Hogan, and Stewart (2014)	Critical thinking	21st-century thinking skills
Eisenberg (2011)	Information literacy	21st-century skills
Eshet-Alkalai and Chajut (2009)	Photo-visual literacy, reproduction literacy, branching literacy, information literacy, socio-emotional literacy	Digital literacy
Gerber and Scott (2011)	Critical thinking	21st-century skills
Gobert, Kim, Sao Pedro, Kennedy, and Betts (2015)	Critical thinking, non-routine problem solving, systems-thinking	21st-century skills
Greene et al. (2014)	Self-regulated learning skills, epistemic cognition	Digital literacy
Greiff et al. (2013)	Complex problem solving	Transversal skills
Gui and Argentin (2011)	Theoretical, operational, evaluation	Digital skills
Hatlevik, Gudmundsdóttir, and Loi (2015)	Retrieve and handle digital information, create and process digital information, digital judgement, digital communication	Digital competence
Helsper and Eynon (2013)	Technical, social, creative, critical	Digital skills
Herde, Wüstenberg, and Greiff (2016)	Complex problem solving	21st-century skills
Heye (2006)	Creativity and innovation	21st-century skills
Hinrichsen and Coombs (2013)	Decoding, meaning making, using, analyzing, personal	Digital literacy
Holt and Brockett (2012)	Self-direction, technology use	21st-century skills
Ibrahim and Jimoh (2013)	Information literacy	Information literacy
Jang (2015)	Problem solving, social communication, technology and engineering, systems thinking, time management	21st-century skills
Janssen et al. (2013)	General knowledge and functional skills, use in everyday life, specialized and advanced competence for work and creative expression, technology mediated communication and collaboration, information processing and management, privacy and security, legal and ethical aspects, balanced attitude towards technology, understanding and awareness of role of ICT in society, learning about and with digital technologies, informed decisions on appropriate digital technologies, seamless use demonstrating self-efficacy	Digital competence
Jara et al. (2015)	Information, communication, ethics and social impact	Digital skills
Järvelä (2015)	Computer-supported collaborative learning, self-regulated learning	Twenty-first century skills
Kingsley and Grabner-Hagen (2015)	Creativity and innovation, critical thinking and problem solving, communication, collaboration	21st-century learning skills
Lee and Kolodner (2011)	Creative design	Twenty-first century skills

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Author/Year	21st-century skills dimensions	Main concept
Lee et al. (2016)	Critical thinking	21st-century learning skills
Levinsen (2011)	Lifelong learning	Digital literacy
Lloyd (2011)	Information literacy	Information literacy
Lombardi, Kowitt, and Staples (2015)	Critical thinking	21st-century skills
Mainert, Kretzschmar, Neubert, and Greiff (2015)	Complex problem solving	Twenty-first century skills
McNicol (2015)	Information literacy	Information literacy
Mengual-Andrés et al. (2016)	Technological literacy, information access and use, communication and collaboration, digital citizenship, creativity and innovation	Digital competence
Mohammadyari and Singh (2015)	Operate different types of computers and access resources, search, find, and evaluate information effectively, use technological tools to accomplish tasks, solve problems, act appropriately in online communities, keep oneself away from harm in digital environments	Digital literacy
Monge and Frisicaro-Pawlowski (2014)	Facility in managing information, sensitivity, versatility	Information literacy
Niepel, Mustafić, Greiff, and Roberts (2015)	Creativity, ethical decision making	21st-century skills
Ng (2012)	Technical, cognitive, social-emotional	Digital literacy
Obschonka, Hakkarainen, Lonka, and Salmela-Aro (2016)	Entrepreneurship	21st-century skills
Osman et al. (2009)	Adaptability and managing complexity, self-direction, curiosity, creativity, risk taking, higher order thinking, sound reasoning	21st-century thinking skills
Quieng et al. (2015)	Communication, relationships and collaboration, critical thinking and decision making, initiative and self-direction	21st-century skills
Ras, Krkovic, Greiff, Tobias, and Maquil (2014)	Collaborative problem solving	21st-century skills
Razzouk and Shute (2012)	Design thinking	21st-century skills
Redecker and Johannessen (2013)	Problem solving, reflection, creativity, critical thinking, learning to learn, risk-taking, collaboration, entrepreneurship	21st-century skills
Romero, Usart, and Ott (2015)	Communication, collaboration, social and cultural skills, creativity, critical thinking, problem solving, productivity in a globalized world, learning to learn skills, self-direction, planning, flexibility, risk taking, conflict management, a sense of initiative and entrepreneurship	21st-century skills
Salas-Pilco (2013)	Communication, citizenship and social, information skills, digital literacy, creativity and innovation, critical thinking, sociocultural sensitivity, autonomy and leadership, learning to learn, productivity, entrepreneurship, life and career, math and science	21st-century competence
Scherer and Gustafsson (2015)	Creative problem solving	21st-century skills
Siddiq et al. (2016)	Accessing, evaluating, sharing and communicating digital information	Digital skills
Smith and Paton (2014)	Information usage, self, communication	Transferable skills
Snow and Katz (2009)	Define, access, evaluate, manage, integrate, create, communicate	21st-century skills
Soh, Osman, and Arsad (2012)	Digital age literacy, inventive thinking, effective communication, high productivity, spiritual value	21st-century skills
Somerville, Smith, and Macklin (2008)	Define, access, evaluate, manage, integrate, create, communicate	21st-century skills
Soule and Warrick (2015)	Creativity, communication, collaboration, critical thinking	21st-century learning skills
Thoman and Jolls (2004)	Thinking critically, applying knowledge to new situations, analyzing information, comprehending new ideas, communicating, collaborating, solving problems, making decisions	21st-century skills
Uzunboylu and Hürsen (2011)	Self-management, learning how to learn, initiative and entrepreneur, acquiring information, digital competencies, decision-taking	Digital competence
Van Deursen et al. (2016)	Operational, information navigation, social, creative, mobile	Digital skills
Voogt and Roblin (2012)	Collaboration, communication, digital literacy, social and/or cultural skills, citizenship, problem solving, critical thinking, creativity, productivity	21st-century competence
Westby (2010)	Visual literacy, computer literacy, media literacies/technology literacy, cultural literacy	Multiliteracy
Woods-Groves (2015)	Persistence, curiosity, externalizing affect, internalizing affect, cognition	21st-century skills
Wüstenberg, Stadler, Hautamäki, and Greiff (2014)	Complex problem solving	Twenty-first century skills
Yang et al. (2014)	Collaboration, cultural awareness	21st-century skills
Young (2015)	Play, performance, appropriation, multitasking, distributed cognition, collective intelligence, judgment, transmedia navigation, networking, negotiation, visualization	New media literacy

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